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PRELIMINARY RESULTS OF COMPUTER AIDED ACOUSTIC IMAGING

John Powers, Miltiades Economopoulos, Eugene Moon, and Harry Vasquez

Department of Electrical Engineering
Naval Postgraduate School
Monterey, California 93940

ABSTRACT

Preliminary results from a computer aided coherent acoustic imaging system are given. The system uses a raster scanned sensor to digitize samples of 1 MHz acoustic fields (both amplitude and phase) sampled at half-wavelength intervals. After transferring the data to computer memory three different types of displays have been used to display and process the data fields as images. The display devices include a black and white video system, a color graphics terminal, and a high resolution color image processing system. The advantages and disadvantages of each display system are discussed along with some of the most useful image processing operations for the acoustic images obtained. These operations include image zoom (i.e., magnification), histogram analysis, dynamic range manipulation, and other interactive capabilities.

INTRODUCTION

The Naval Postgraduate School (NPS) has been developing a general purpose non-real time test bed to investigate a wide variety of acoustic imaging techniques especially those involving computer processing and image processing of the collected data. The data acquisition portion (Fig. 1) of the system consists of a precision-screw-controlled point receiver scanned in a pattern determined by the physical setup. This receiver coherently detects the sound pattern. The most frequently used pattern to date has been a raster scan of 64 x 64 data points (sampled at

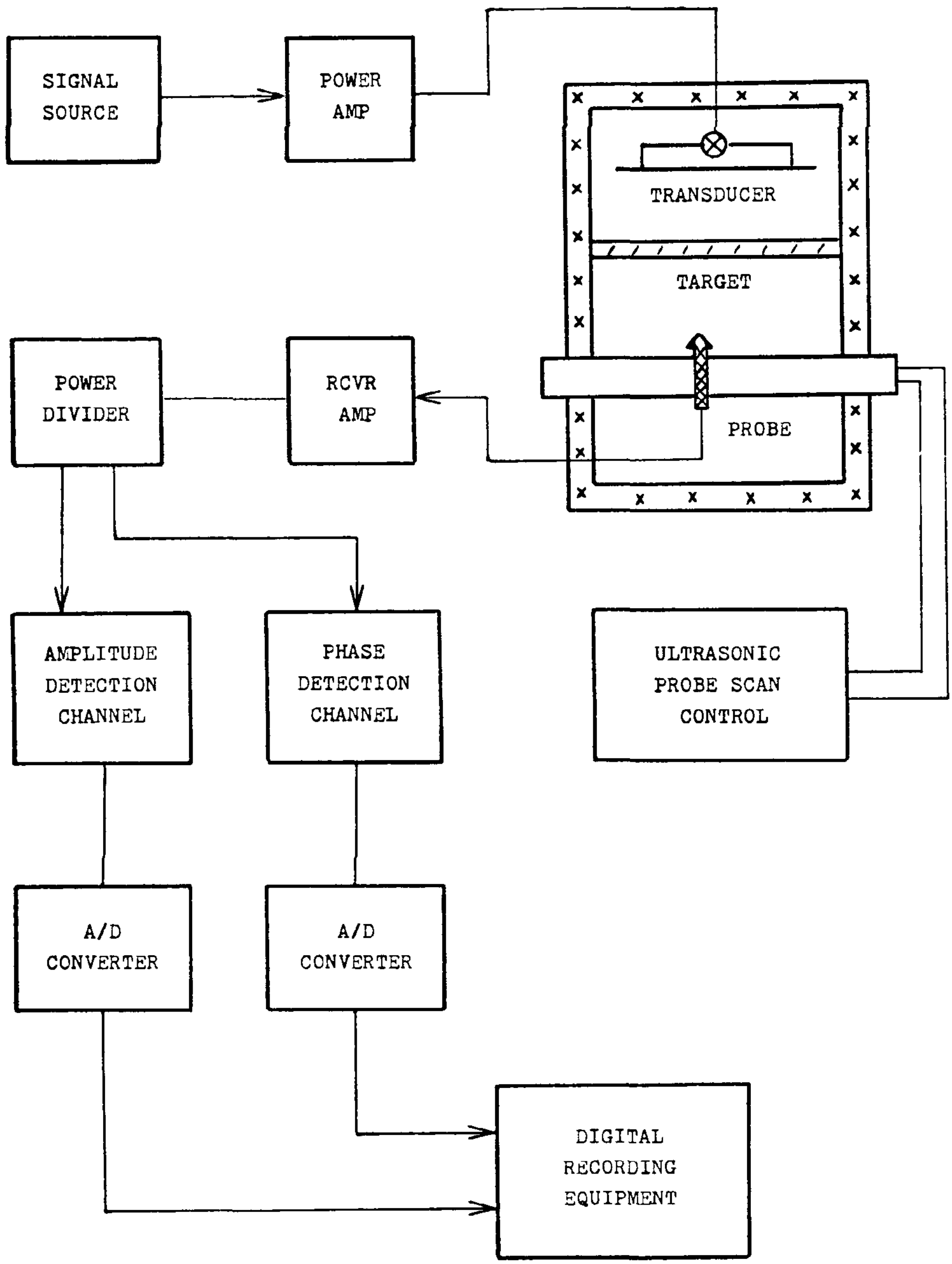

Fig. 1. Data acquisition portion of NPS acoustic imaging system.

half wavelength intervals for the 1 MHz operating frequency) although other scans can be easily accommodated. In the present acquisition system the scanner is controlled by a hardware controller with the data conversion and storage (on paper tape or cassette recorder) controlled by a microprocessor[1]. Presently a system is being implemented with a LSI-11 microcomputer providing the scan control and the data storage on to a floppy disk medium[2] to allow increased ease in reconfiguring the scanning geometry. Once the data is recorded it can be transformed to a large control computer for processing in depth or to a smaller minicomputer that controls the various displays used and their associated image processing routines. Additional simple processing operations can be done in the minicomputer but complicated algorithms manipulating the entire complex data array would require the use of the array processor in the minicomputer system or the larger central computer. In this fashion a wide variety of processing techniques can be applied to data by implementing processing algorithms. Additionally a wide variety of image processing algorithms are implemented in some of the display systems further extending the flexibility.

This paper presents representative preliminary images from the data acquisition system and the results of some of the simple image processing operations that can be applied to the images. Two of the display systems can use color for pseudo-color representation of the gray scales of the images. This allows the operator to pick out brightness changes that are not obvious in the black-and-white images. Experience has shown that while arbitrary use of pseudo-color assignment has marginal value, limited use does have a capability of presenting more pleasing images to the operator. Due to an inability to represent color images in this volume only black-and-white images will be presented here.

RAMTEK GX100A SYSTEM

The RAMTEK system is a high resolution graphics terminal displaying 240 x 640 pixels with a wide variety of annotation capability. The system has no image processing capability however and was used as a beginning capability. The system has 16 levels each of three colors allowing a wide variety of colors to be represented. The images were primarily used to study pseudo-color presentation of the images. Fig. 2 shows a black-and-white representation of such an image. The object is the transmission pattern (showing the log of the amplitude) immediately behind a two inch aperture of an acoustic lens. Testing of such images proved that a pseudo-color assignment similar to the visible spectrum order of colors as the best with the cooler colors

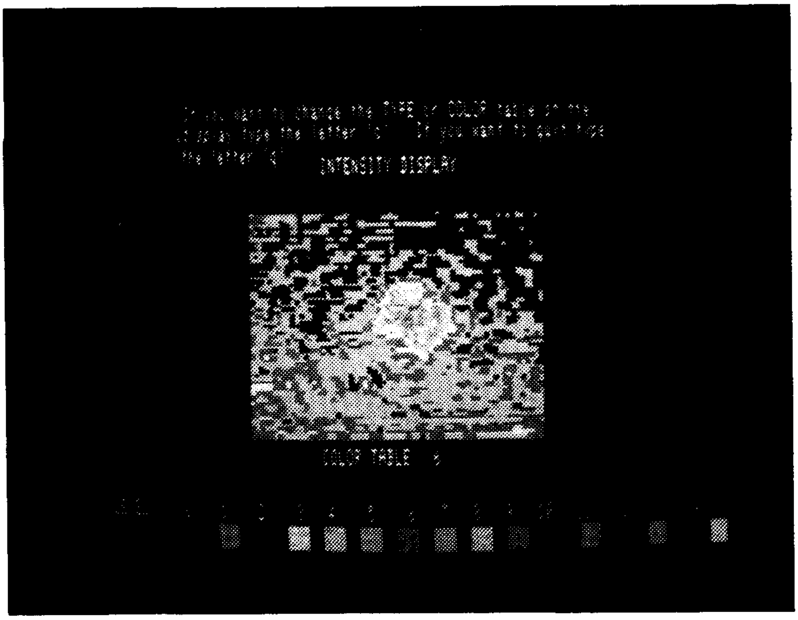

Fig. 2. B/W representation of image of acoustic lens.

representing low values of data and the hotter colors representing the higher values.

EYECOM SYSTEM (EXPANDED)

A system with more display and processing capability is the Spatial Data System's EYECOM. This system consists of a video digitizer and a display. The display of the expanded system is capable of representing 256 gray levels in each of its 640 x 430 pixels. The system includes an annotation capability and a wide variety of image processing functions. The most useful of these include the capability to magnify or "zoom" an area of interest (Fig. 3), to perform a histogram on the image (i.e., displaying the number of pixels having a given graph scale), and to modify the histogram of the display. This latter operation performs contrast enhancement for some images. For example, Fig. 4 displays the same object as Fig. 3 with the gray scales between levels 75 and 100 (i.e., where most of the data of Fig. 3 resides) "stretched" to lie between levels 35 and 200. Values on the original histogram are linearly interpolated to provide the new values. The object in Figs. 3 - 9 are the transmitted sound through a letter "N" cut out of a cork absorbing mask. As seen the images are negative images due to the acquisition system

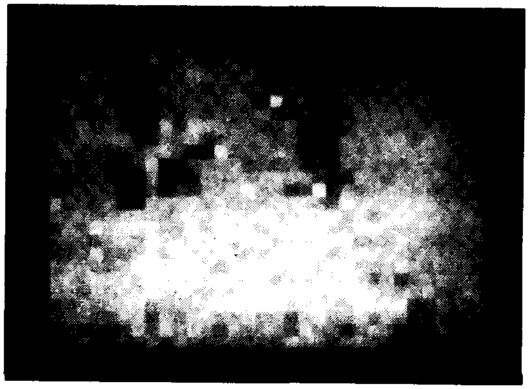

Fig. 3. Zoomed Eyecom image of letter.

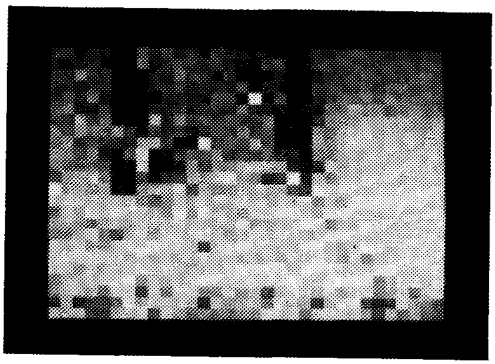

Fig. 4. Dynamic range manipulation applied to the image of Fig. 3.

electronics and are reversed due to the recording geometry. The vertical strokes of the letter are 2 2/3 acoustic wavelengths wide. The diagonal stroke is 1 1/3 wavelengths wide. Because of the wide dynamic range encountered in acoustic images the amplitude data has been logarithmically compressed. Removing the compression returns the high contrast but the compressed data provides a more satisfactory image to the operator. Most of the images here are presented using the compressed data unless otherwise noted. (The phase however does not suffer from this dynamic range problem due to its periodic nature and is recorded linearly.)

Averaging techniques as might be expected reduce the graininess of image with an attendant loss in resolution. Fig. 5

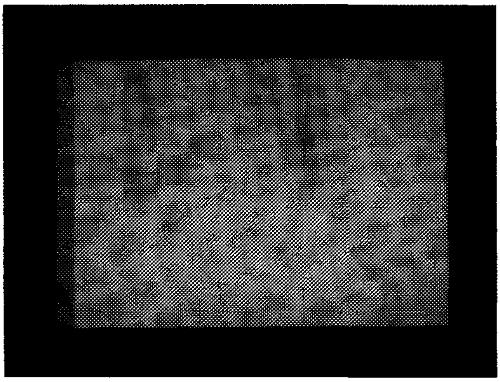

Fig. 5. Averaged image.

shows an image in which an averaging routine replaces the pixel's value by the average value of all of the pixels in a 3 x 3 box around the center. The dynamic range is compressed and the image is smoother. Other routines can be used for edge enhancement. Fig. 6 shows a processed image with a gradient operator that approximates the function:

$$\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2 \tag{1}$$

The vertical edges of N are highlighted as are the other noisy places where the data changes significantly. A combination of averaging to reduce the noise and then edge detection would produce a better image. Another operator performing the Laplacian

$$\frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2} \tag{2}$$

operation is also useful in finding and accentuating edges.

COMTAL VISION/ONE SYSTEM

The COMTAL system is a powerful image processing system with extremely high resolution. As used in this study the basic system had 16 levels in each of three colors or 16 gray scales over 1024 x 1024 pixels. When fully expanded the system will have 256 levels. The high frequency response of the circuit allows full use of the dynamic range of the gray scale between adjacent pixels producing an image extremely high fidelity even with 16 gray scales. The system has a full complement of image processing

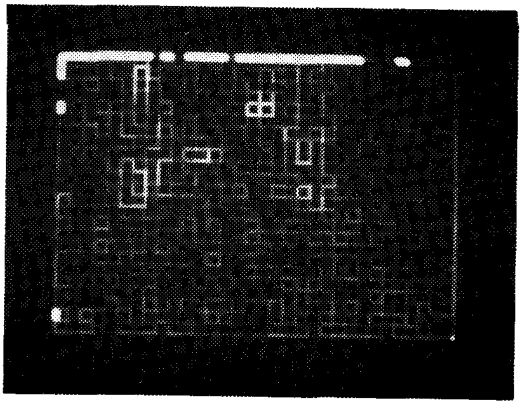

Fig. 6. Gradient operator image.

capabilities many of which can be implemented on a frame-to-frame basis (i.e., in 1/30 of a second). Other routines can be implemented in software. Figures 7 and 8 show the letter "N" amplitude data; Fig. 7 is linear amplitude data while Fig. 8 is logarithmic data. Figure 9 shows the phase data for the letter "N" illustrating that there is considerable object information in the phase. No processiing has yet been attempted to the phase data.

Figure 10 shows the logarithmic data for a cruciform cutout object. Each of the squares is approximately 6 2/3 wavelengths across. The 16 level histogram of this image is shown in Fig. 11. One of the major assets of the COMTAL system is the ability of the operator to manipulate the histogram pattern interactively. This manipulation can be graphical using a track ball input or analytic

Fig. 7. Comtal linear amplitude data.

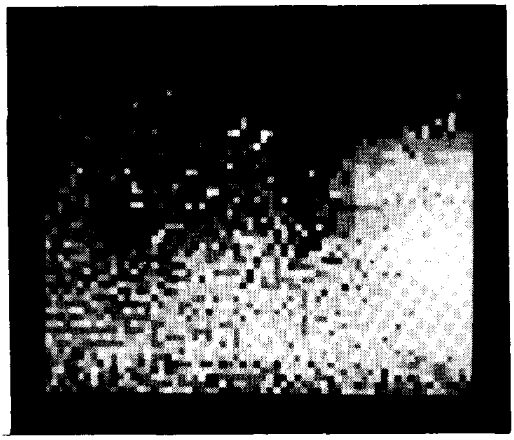

Fig. 8. Logarithmic amplitude data.

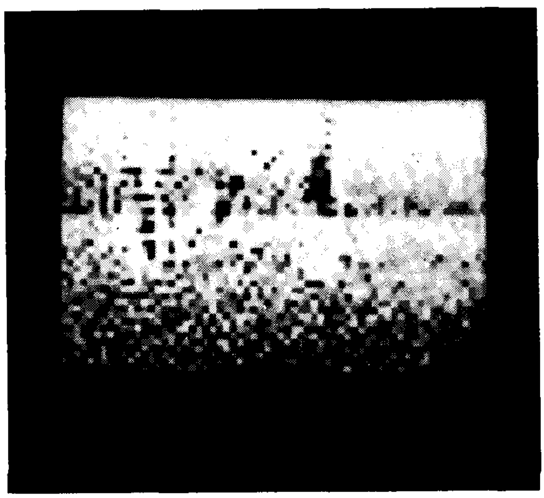

Fig. 9. Phase data of letter object.

expressions as typed in on the keyboard. An example of the former operation is shown in the transfer function of Figure 12. This "hard-limiting" function will zero the intensity of any pixels having a value greater than 5 and will produce maximum intensity for all pixels with a value less than or equal to 5 thereby reversing contrast and eliminating much of the noise (as well as some of the object information) as shown in the processed image of Fig. 13.

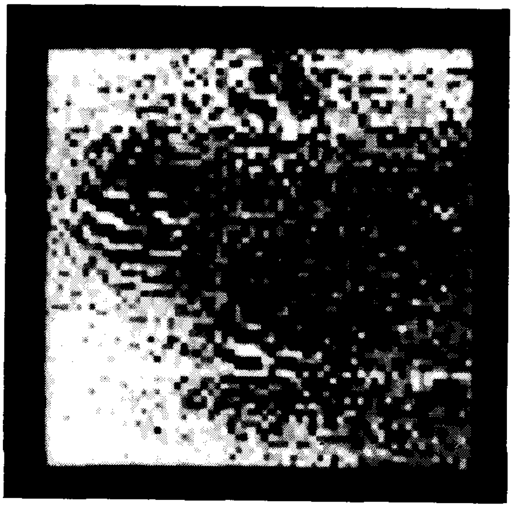

Fig. 10. Logarithmic amplitude of cruciform.

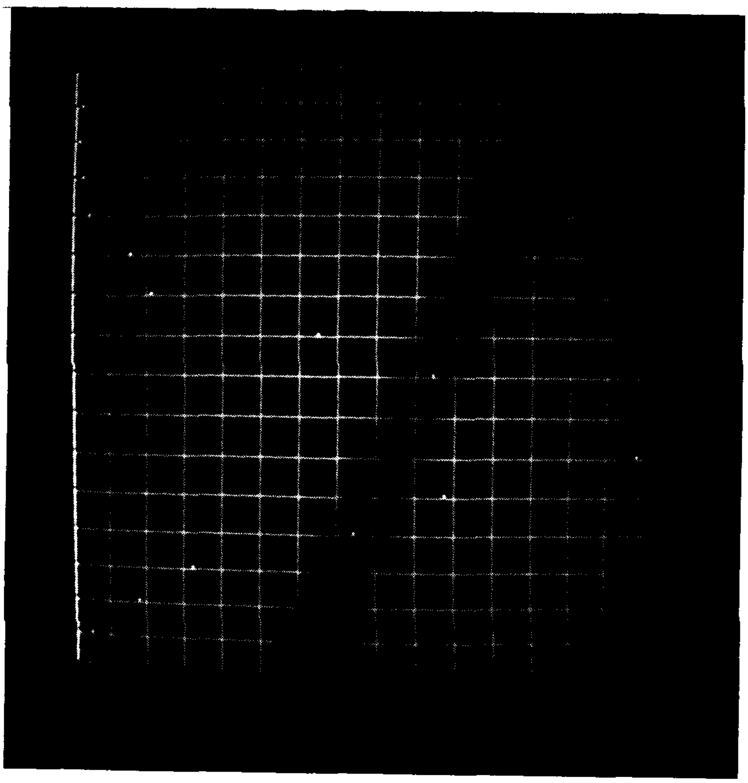

Fig. 11. Histogram of log amplitude image.

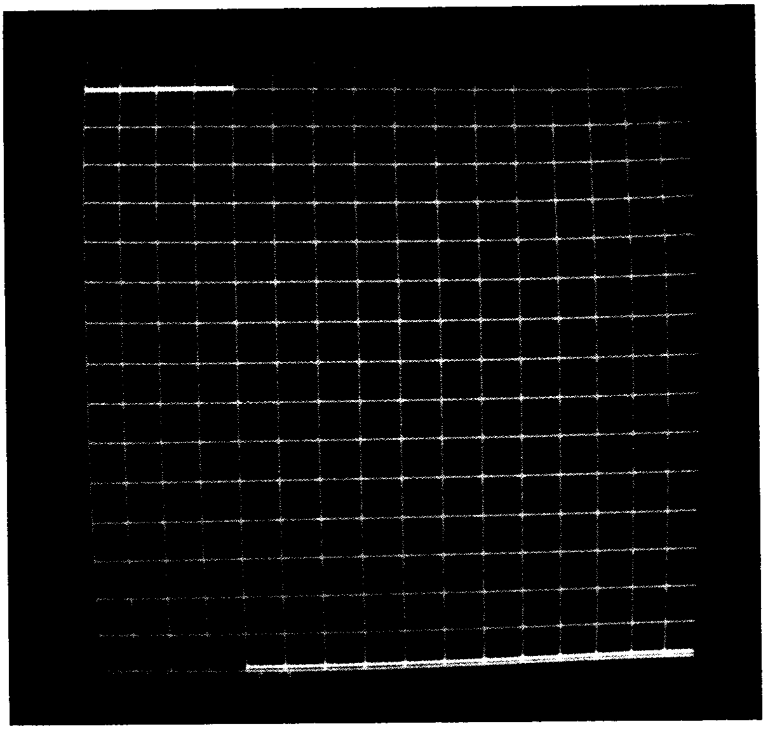

Fig. 12. Transfer function applied to histogram. Horizontal axis is the gray level of the input, vertical scale is the gray level of the output.

SUMMARY

This paper has presented some of the preliminary images obtained with the NPS acoustic imaging system. Various data display systems have been used with the newly acquired COMTAL system showing the most promise. Application of the various image processing techniques built into the systems demonstrate the requirement for an interactive system since the improvement of the images is highly subjective and the order of processing as well as the parameters used in the processing techniques are image dependent.

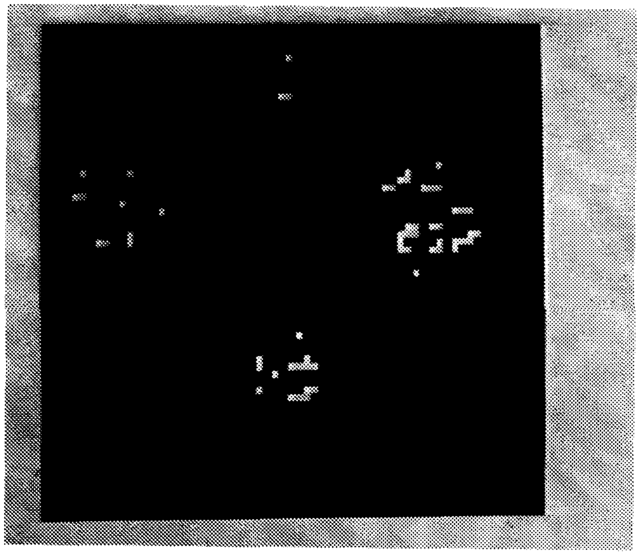

Fig. 13. Processed image.

ACKNOWLEDGEMENT

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